

*Clean Copy of the Specification*

## **SENSOR AND METHOD FOR THE PRODUCTION THEREOF**

### **PRIORITY INFORMATION**

This patent application claims priority from International patent application PCT/EP2005/050418 filed February 1, 2005, German Patent Application No. 10 2004 005 927.6 filed February 6, 2004, and German patent application 10 2004 035 551.7 filed July 22, 2004, which are hereby incorporated by reference.

### **BACKGROUND OF THE INVENTION**

This invention relates in general to sensors and in particular to a sensor, for example a gas sensor, acceleration sensor, or pressure sensor, with components containing silicon, where electrical signals can be read when analytes are present or in case of mechanical deformation. Moisture in the air forms a thin film of water on the surface of material containing silicon, which leads to increased surface conductivity. Leakage currents from this increased conductivity represent a problem with regard to stability and signal quality for many sensors that are in contact with air.

To prevent the effects of moisture on sensor systems, the sensors are encapsulated if possible. If contact with the surrounding air is necessary for proper operation of the sensor, for example gas sensors, passive water-repellent membranes may be used. Also, heating to temperatures well above 100 °C solves the problem, but this is associated with considerable expenditure of energy.

There is a need for a sensor with a semiconductor body whose moisture sensitivity and leakage current are substantially reduced.

## **SUMMARY OF THE INVENTION**

Silanization familiar from glass coating can also be applied to semiconductor technology. In this case, a monolayer of the hydrophobic molecular chains that suppress the adsorption of water molecules is formed on a surface containing silicon. All hydrophobic molecular chains that participate in a stable bond with the surface are suitable for this application. Thus, no continuous water film that favors the unwanted surface conductivity can form, up to high atmospheric humidity levels – almost 100%.

Structural elements containing silicon can operate in ambient air after silanization without heating or encapsulation, and without the problem of interference from surface currents induced by moisture.

In general terms, the semiconductor body used as the base in this silicon technology is silanized. Either pure silicon or silicon compounds present superficially can be treated.

The fields of use of such semiconductor sensors based on silicon and insensitive to moisture, for example, are gas sensors, pressure sensors, or in general any sensors that come into contact with essentially atmospheric moisture when in operation. Hence analytes such as target gases are detected by gas sensors, and mechanical shape or deformation changes are detected by pressure sensors or acceleration sensors.

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a graph that illustrates a comparison of a silanized hydrogen sensor and a sensor with no hydrophobic covering layer;

FIG. 2 is a graph that illustrates various humidity levels and additional gases; and

FIG. 3 is a cross-sectional illustration of a gas sensor in the form of a floating gate FET.

## **DETAILED DESCRIPTION OF THE INVENTION**

The functional principle of silanization on silicon nitride and oxidized polycrystalline silicon was tested specifically on a gas sensor, in particular a floating gate field effect transistor (FGFET). Other embodiments of FETs can also be used, for example suspended gate FETs. FIG. 3 illustrates schematically the structure of the FGFETs used. The potential change occurring on a sensitive layer from gas impingement is fed to the MOSFET by the voltage divider extending between a floating gate and a capacitive well (electrode), and leads to a current change between a drain and a source. A floating electrode (gate) is covered with a nitride or oxide layer to protect it against interfering leakage current. Nevertheless, potentials can still be coupled in capacitively through a conducting moisture film on this passivation. To prevent this, an equipotential surface, for example a guard ring, is placed on the surface around the sensitive gate. At higher atmospheric humidity levels (>50%), increased surface currents nevertheless occur, which lead to severe signal drift. To prevent this, it is necessary to prevent the formation of a moisture film. Hydrophobic molecular chains are then applied to the existing passivation by silanization before a hybrid gate is mounted. Since the adhesive bond of the gate then no longer adheres to this layer, additional aluminum-adhesive pads are

necessary on the chip, since the silanization does not adhere there. Because of this process, the unheated gas sensors thus produced are almost completely stable even at high humidity levels. Subsequent measurement shows a comparison between a silanized hydrogen sensor and an untreated sensor at various humidity levels (see FIG. 1).

The sharp drift and "distortion" of the hydrogen signals is effectively suppressed by silanization. The remaining small moisture steps in the silanized signal are caused by the dipole signal of water on the sensitive platinum layer and no longer interfere.

To gain precise information on surface conductivity, the above FGFET was put together with surfaces with no hybrid gate, both silanized and unsilanized. To measure the very small currents qualitatively, use was made of the sensitivity of the floating gate. The guard ring was controlled in both chips with a square-wave generator and the moisture-dependent coupling to the transistors was measured. A very low frequency was chosen (0.1 Hz) to preclude frequency-dependent effects in the RC circuits. The higher the surface conductivity, the larger the coupling of the square-wave generator into the transistor. FIG. 2 illustrates a comparison of these measurements with various humidity levels and additional gases. The current in the transistors is kept constant by feedback electronics. The resulting signals originate from the feedback control circuit and thus show the potential applied to the floating gate.

It can be seen that all moisture effects have disappeared after silanization. The remaining coupling is only capacitive. The reaction of the nitride to  $\text{NO}_2$  has disappeared in the silanized version. Increased sensitivity to  $\text{NH}_3$  exists instead. This is to be expected with the trichlorosilane used as the starting material for silanization, especially n-octadecyltrichlorosilane, since alkalis like ammonia attack the bonds to the nitride

passivation. On the other hand, the layer is especially stable to acids (for example,  $\text{NO}_2$ ).

The samples with oxidized polysilicon show the same behavior.

Although the present invention has been illustrated and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is:

**IN THE DRAWINGS:**

The attached sheet of drawings includes changes to FIGs. 1-3. These sheets replace the original sheets that included FIGs. 1-3.